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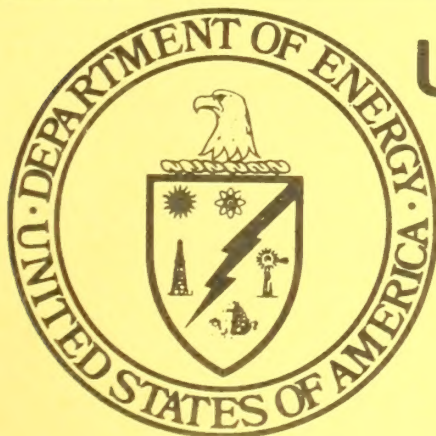
Aleph 1215987

SOLAR/2068-79/06

Monthly Performance Report

COLUMBIA GAS SYSTEM

JUNE 1979



U.S. Department of Energy

National Solar Heating and
Cooling Demonstration Program

National Solar Data Program

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MONTHLY PERFORMANCE REPORT
COLUMBIA GAS SYSTEM
JUNE 1979

I. SYSTEM DESCRIPTION

The Columbia Gas System site is a three-story, 25,000 square foot office building in Columbus, Ohio. The solar energy system, which was added to the existing building, is designed to provide 30 percent of the building's total annual thermal energy requirements. The expected annual solar contributions for the three subsystems are 32 percent for space heating, 23 percent for space cooling, and 70 percent for hot water. The collector subsystem is comprised of 44 Honeywell, Inc. north/south tracking, concentrating collectors, facing five degrees east of south. The collectors rotate about an approximate east/west axis to track the daily variation in the sun's elevation angle, and direct the solar radiation toward the absorber tube mounted above the reflectors. The collector array is arranged in 11 rows with a total gross area of 2,978 square feet.

The collector loop heat transfer fluid is a 47 percent solution of Dowtherm SR1. Collected solar energy is transferred to the loads, or to a 5,000-gallon water thermal storage tank via a liquid-to-liquid heat exchanger. Incoming city water is heated for use as domestic hot water on demand, by passing it through another heat exchanger, or preheat coil, located within the water thermal storage tank. A conventional 50-gallon gas-fired hot water heater augments this solar hot water energy from the tank heat exchanger. Solar heated water is also used for space heating and cooling. This thermal energy is supplied either to fin tube heating coils for space heating, or to an absorption chiller for space cooling. When solar energy is insufficient to satisfy heating or cooling demands, thermal energy is provided by an auxiliary gas-fired boiler.

The solar energy system, shown schematically in Figure 1, has six modes of operation which are defined as follows:

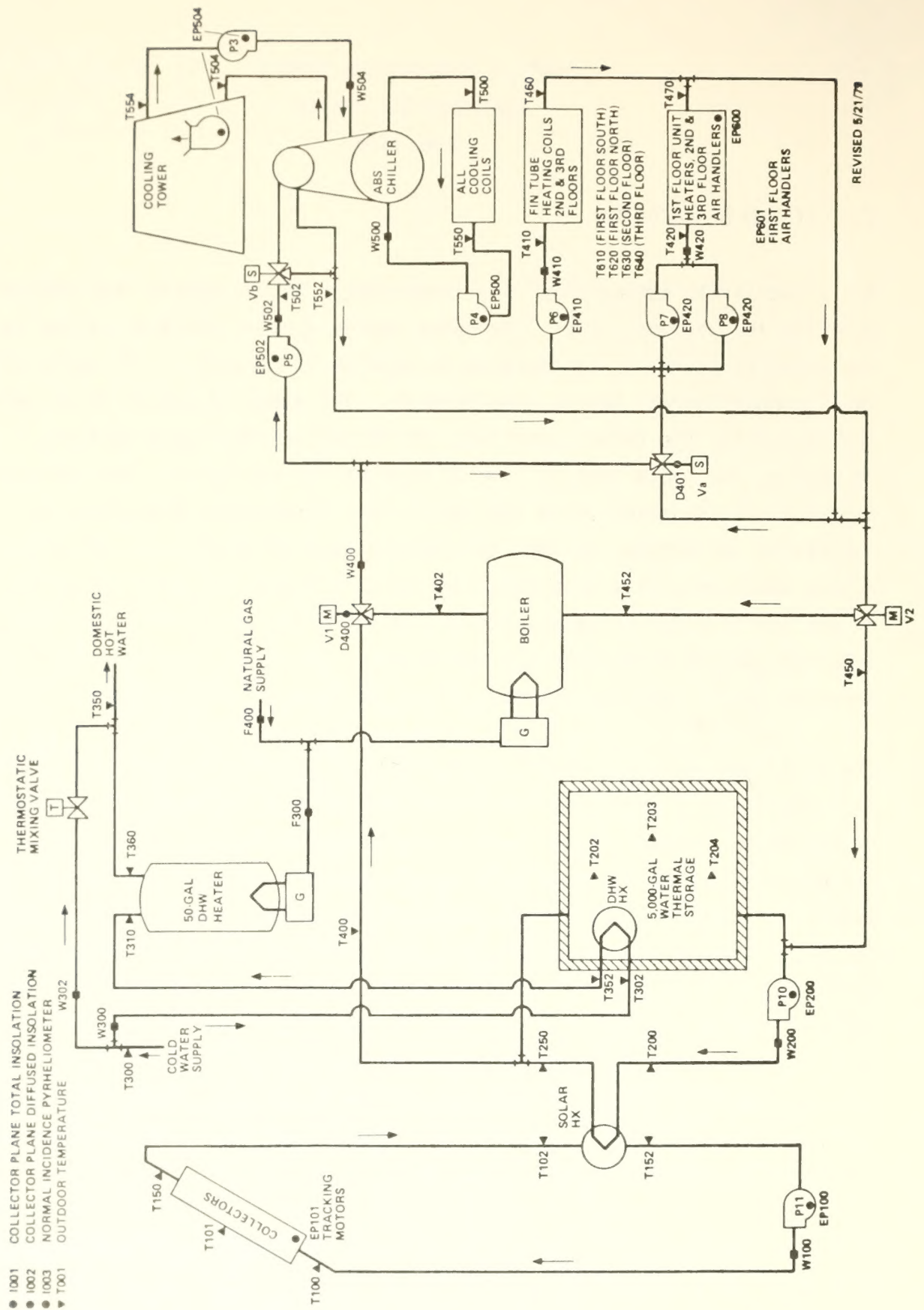


Figure 1. COLUMBIA GAS SYSTEM SOLAR ENERGY SYSTEM SCHEMATIC

Mode 1 - Collectors Tracking: In this mode, the collectors track the sun to collect solar energy. This mode is entered by a four-step process:

- 1) If measured insolation in the principal plane of the collector is greater than approximately $175 \text{ Btu/ft}^2\text{-hr}$, storage tank temperature is less than 210°F , wind speed is less than 20 mph, and collector array outlet temperature is less than 240°F , then collector loop pump P11 is turned on. At this time a closed valve (not shown in Figure 1) allows collector loop flow to bypass the primary side of the collector loop heat exchanger.
- 2) If flow is detected in the collector loop by a differential pressure switch, the collectors are rotated to the correct tracking position.
- 3) When the collectors have reached the tracking position, a differential temperature controller checks the collector outlet temperature to determine if it is at least 20°F greater than the storage temperature.
- 4) If this temperature differential is detected, storage loop pump P10 is turned on to allow flow through the secondary side of the heat exchanger, and the collector loop heat exchanger bypass valve is opened to allow flow through the primary side of that heat exchanger.

The collectors remain in Mode 1 until conditions are met for returning the system to Mode 2 or Mode 3. While in Mode 1, if the collector outlet temperature drops to less than 5°F above the storage tank temperature, then storage loop pump P10 is turned off and the collector loop bypass valve is closed to bypass the primary side of the heat exchanger. The collectors continue to track the sun and collector loop circulation is maintained until the 20°F temperature differential is again met, or until conditions for return to Mode 2 or Mode 3 are met.

Mode 2 - Collectors Stowed: While in Mode 2, the collector reflectors are turned downward toward the roof, or stowed, to prevent collector damage from excessive heat or the elements. This mode is entered from Mode 1 by a two-step process:

- 1) While in Mode 1, if one or more of five conditions is met, the collectors are placed in the stowed position. These five conditions are: a. wind speed greater than 30 mph for approximately 10 seconds; b. measured insolation in the principal plane of the collector less than approximately 150 Btu/ft²-hr; c. differential pressure switch senses no flow in the collector loop; d. collector array outlet temperature greater than 252°F; and e. storage tank temperature greater than 220°F.
- 2) When the collectors have returned to the stowed position, storage loop pump P10 is turned off, the primary side of the collector loop heat exchanger is bypassed, and collector loop pump P11 is turned off.

If the collectors were stowed due to an absence of collector loop flow, manual reset is required before Mode 1 can be reentered. However, if the collectors were stowed for any of the other four conditions, Mode 1 will be reentered automatically whenever its entry conditions are met.

Mode 3 - Collector Emergency Stow: This mode is used to stow the collectors in the event of a power failure. This mode is entered from Mode 1 by a four-step process:

- 1) If voltage-sensitive relays in all tracking motor phases detect that any phase has dropped below 70 percent rated voltage, an emergency generator is activated.
- 2) When the generator has reached operating voltage, transfer switches automatically transfer the control system and collector loop pump P11 from the normal building power to the emergency generator.

- 3) The collector controls cause the collectors to move from the tracking position to the stowed position in four stages (or steps) using power from the emergency generator. During each of the four stages, approximately one-fourth of the total collector array will be stowed.
- 4) When all collectors have been stowed, the collector loop pump is turned off. The controls are then reset for return to Mode 1 operation when building power is restored.

When building power has been restored, power transfer switches automatically return to building power. After a 10-minute delay, the emergency generator is turned off, and Mode 1 is reentered if its entry conditions are met.

Mode 4 - Solar Energy-to-Space Heating/Cooling: This mode occurs when there is a demand for space heating or cooling and the storage tank temperature exceeds the minimum value suitable for the loads. If summer operation has been manually selected by a master controller, this value is 190°F. If winter operation has been selected, solar energy flow begins at 150°F. These temperature settings are nominal values and can be adjusted by site personnel if desired. When this control temperature setting has been exceeded, the boiler gas supply is immediately shut off and flow continues through the boiler for two minutes to deplete some of the residual energy. The load supply lines are then switched from auxiliary to solar energy. When the storage temperature has dropped by 2°F, Mode 4 is terminated. If storage loop pump P10 is operating while Mode 4 is active, part of the energy supplied to the loads will come directly from the heat exchanger and the balance will come from storage. If this pump is not operating, all the solar energy supplied to the loads originates from storage.

Mode 5 - Collector-to-Storage: This mode occurs while the collectors are operating in Mode 1, but the conditions for Mode 4 entry are not met.

While in this mode, solar energy is routed directly from the collectors to storage via the collector loop heat exchanger. Mode 5 is terminated upon entry to Mode 2, 3 or 4.

Mode 6 - Storage-to-Domestic Hot Water: This mode occurs while a domestic hot water demand is present. When hot water is being used, makeup cold water flows by supply pressure through the hot water preheat coil in the storage tank. This makeup water absorbs stored solar energy as it passes enroute to the conventional hot water heater.

In addition to these six modes, individual collector rows can be stowed if they overheat. Each of the 11 individual collector rows has a separate control system sensor indicating absorber tube temperature. If the temperature of an individual collector row absorber tube exceeds 260°F, that collector row is stowed. When the temperature then drops below 220°F, that collector row resumes tracking. If the collector row overheats a second time, a manual reset is required to restart the individual collector row.

II. PERFORMANCE EVALUATION

The system performance evaluations discussed in this section are based primarily on the analysis of the data presented in the attached computer-generated monthly report. This attached report consists of daily site thermal and energy values for each subsystem, plus environmental data. The performance factors discussed in this report are based upon the definitions contained in NBSIR 76-1137, Thermal Data Requirements and Performance Evaluation Procedures for the National Solar Heating and Cooling Demonstration Program.

A. Introduction

The solar energy system at the Columbia Gas site collected energy on 23 days during June and supplied 3.0 percent of the total system thermal energy load. Space heating, space cooling, and domestic hot water heating received 7.3 million Btu of solar energy during the month. Although average storage temperatures exceeded the 150°F control set point for

heating on 27 days during the month, little solar energy was used for space heating due to the master controller being set for summer operation, which has a 190°F set point. Space heating was required on 28 days. Space cooling was required each day of the month.

B. Weather

The long-term average outside ambient temperature for Columbus in June is 70°F. Also, Columbus has a long-term average of 13 heating degree-days, and 175 cooling degree-days in June. This month the actual outside ambient temperature average was 72°F. There were three heating degree-days and 197 cooling degree-days. The measured insolation in the plane of the pyranometers (five degrees east of south, with a tilt of 40 degrees from the horizontal) averaged 1,583 Btu/ft²-day, which is less than the expected long-term average of 1,814 Btu/ft²-day. This reduction in available solar energy was responsible for some decrease in solar energy system performance.

C. System Thermal Performance

Collector - Of the 141.4 million Btu of incident solar energy on the collector array during June, 58.7 million Btu were incident on the array while collection and storage pumps P11 and P10 were operating. The system collected 18.7 million Btu, or 13.2 percent of the total insolation incident on the collector array. This was 22.5 percent of the insolation incident while the pumps were operating. Since these collectors are tracking concentrators, they use only the direct or beam component of solar energy. While pumps P10 and P11 were operating and the collectors were tracking the sun, a total of 54.1 million Btu of direct solar energy was incident on the collector array. Of this incident direct solar energy, 34.6 percent was collected by the array, which agrees closely with the 37.0 percent collected in May. During June, pumps P10 and P11 and the collector tracking motors used a combined total of 1.6 million Btu of electrical energy.

Storage - Of the 18.73 million Btu of solar energy collected, 14.82 million Btu were delivered to the storage tank. A total of 3.13 million Btu of solar energy was extracted from the storage tank. A total of 2.03 million Btu of solar energy was extracted from the storage tank to pre-heat domestic hot water. The net energy in storage decreased by 0.30 million Btu during the month. A summary of energy in and out of storage is shown below. The net thermal loss from storage was 11.99 million Btu.

14.82	million Btu	-	energy to storage tank
<u>3.13</u>	million Btu	-	energy extracted from storage tank
11.69	million Btu		
<u>0.30</u>	million Btu	-	energy decrease in storage tank
11.99	million Btu	-	thermal loss from storage tank

Domestic Hot Water Load - The domestic hot water subsystem operated continuously during June. The daily average hot water consumption was 141 gallons for the month. The 2.17 million Btu of energy added to the subsystem were comprised of 2.03 million Btu of solar energy and 0.14 million Btu of auxiliary thermal energy, giving a hot water solar fraction of 93 percent. Hot water was supplied at an average temperature of 120°F and was replaced with cold water at an average temperature of 71°F.

Space Heating Load - Space heating was required on 28 days during June. The space heating load of 29.1 million Btu was supplied by 28.7 million Btu of auxiliary thermal energy and 0.4 million Btu of solar energy. In order to provide the auxiliary thermal energy, 64.4 million Btu of natural gas were required. The ratio of auxiliary thermal energy used to natural gas supplied showed a boiler conversion efficiency of 44.6 percent. As previously mentioned, storage temperatures must exceed 150°F before solar energy can be used for space heating. Although average storage temperatures exceeded 150°F on 27 days during June, the space heating requirements were largely provided from the boiler due to a 190°F requirement for water temperature for the absorption chiller.

Space Cooling Load - The absorption chiller required 301.4 million Btu to provide 124.8 million Btu of chilled water. Solar energy supplied 5.6 million Btu and the auxiliary boiler supplied 295.7 million Btu to the absorption chiller. In order for solar energy to be used for space cooling, the temperature in the top of the storage tank must be greater than or equal to 190°F to run the absorption chiller. If this temperature is reached, solar energy for space cooling can be supplied directly from the collector array via the heat exchanger, from storage, or from a combination of both. During this month, the top storage temperature exceeded 190°F on five days. Total elapsed time for the five days was approximately two hours. Calculations indicated 458.0 million Btu of natural gas were required to provide auxiliary thermal energy. The coefficient of performance of the absorption chiller was 0.41. The total space cooling load in June was 124.8 million Btu.

D. Observations

The solar energy system supplied three percent of the system thermal energy requirement. For the previous six months of system operation, the net measured solar contribution was between 0.66 and 5.0 percent, which contrasts to an expected solar contribution of 30 percent. The decrease in solar contribution from five percent for May to three percent for June can be partially attributed to a decrease in operational time for the solar energy system. This was discussed with Philip Dechow of Columbia Gas Corporation. If the set point of the pyranometer which energizes the rotate mechanism for the collectors is adjusted for the proper sun angle, more operational time for the solar energy system would result.

A problem due to inadvertent flow of hot water through heating coils at the wrong time is adding to the cooling load. For example, when the absorption chiller was operating on June 9 as much as 90°F temperature drop across the T470 and T420 sensors was observed from 0000 to 2400 hours with no flow indication on flowmeter W420. This is due to a backflow forced through pumps P6, P7 and P8 and adds appreciably to the total building cooling load. The actual added load is unknown. During the transitional season

this problem will not be easily solved. When cooling only is required, the heating coils can be isolated with manual valves and the problem will be eliminated.

On July 10, 1979, the problem was discussed with Philip Dechow of Columbia Gas Corporation. Evidently the same backflow problem occurred last year. At that time existing check valves were removed, examined and reinstalled. The reason they do not prevent this backflow is unknown. Philip plans to close the manual valves around the heating coil and eliminate this problem for the summer.

A system problem exists which interferes with utilization of stored solar energy. For example, the space heating subsystem report shows that 28.7 million Btu of auxiliary thermal energy was used for space heating and 0.4 million Btu of solar energy was used for space heating; yet, the average temperature of stored water exceeded 150°F on 27 days.

The stored solar energy was available for space heating but not used. This appears to be due to "summer operation" which is manually selected by a master controller (see Section I, Mode 4). The summer operation selection causes solar energy flow from the storage tank to begin when the temperature is greater than 190°F. The heating system could efficiently use water with a temperature less than 190°F. Re-examination of the automatic control system is suggested with a goal of increasing the percent of solar energy utilized from the storage tank for space heating.

E. Energy Savings

The Columbia Gas solar energy system resulted in a savings of 12.08 million Btu of natural gas during the month. In order to operate the solar energy system, 1.58 million Btu of electrical energy were used to operate the collector tracking motors and pumps. To allow a direct comparison of natural gas savings with electrical expense, an efficiency of 30 percent was assumed for converting natural gas to electricity and transmitting that energy to

the user. This shows that the 1.70 million Btu of electrical energy were equivalent to 5.27 million Btu of natural gas. Subtracting this from the solar energy fossil fuel savings of 12.08 million Btu gave a net energy savings of 6.81 million Btu of natural gas when compared to a conventional system. Computed cumulative energy savings for October through June were 34.52 million Btu of equivalent fossil energy.

III. ACTION STATUS

The solar energy system collected energy on 23 days during June and is still being refined by site personnel. As this activity continues, the solar energy system will become fully operational and carry a larger portion of the system load. Collector array modifications are in progress to improve tracking accuracy, which will increase the solar energy contribution. Site personnel are also checking the storage tank to determine the source of high thermal losses.

SOLAR HEATING AND COOLING DEMONSTRATION PROGRAM

MONTHLY REPORT SITE SUMMARY

SITE: COLUMBIA GAS, COLUMBUS, OHIO
REPORT PERIOD: JUNE, 1979

SOLAR/9999-79/06

SITE/SYSTEM DESCRIPTION: THE COLUMBIA GAS SOLAR ENERGY SYSTEM PROVIDES HEATING, COOLING AND DOMESTIC HOT WATER FOR A 25,000 SQ FT BUILDING. AUXILIARY HEATING AND COOLING ENERGY IS PROVIDED BY A NATURAL GAS BOILER WHICH FIRES A 100 TON ABSORPTION CHILLER OR FLOWS THROUGH FINNED-TUBE HEATING COILS AS THE LOAD DEMANDS. A SEPARATE DOMESTIC HOT WATER HEATER IS USED. THE COLLECTOR ARRAY CONSISTS OF 44 NORTH-SOUTH TRACKING HEAT EXCHANGERS WITH A TOTAL EFFECTIVE AREA OF 2978 SQ FT. THE COLLECTOR FLUID IS A 47 PERCENT SOLUTION OF DOW THERM SRI. THE SOLAR ENERGY IS STORED IN A 5000 GALLON THERMAL ENERGY STORAGE TANK.

GENERAL SITE DATA:

INCIDENT SOLAR ENERGY 141.415 MILLION BTU
COLLECTED SOLAR ENERGY 474.86 MILLION BTU
AVERAGE AMBIENT TEMPERATURE 18.736 BTU/SQ.FT.
AVERAGE BUILDING TEMPERATURE 62.91 DEGREES F
ECSS SOLAR CONVERSION EFFICIENCY 72
ECSS OPERATING ENERGY 76
TOTAL SYSTEM OPERATING ENERGY 9.05 MILLION BTU
TOTAL ENERGY CONSUMED 92.545 MILLION BTU
635.267 MILLION BTU

SUBSYSTEM SUMMARY:

LOAD	HOT WATER	HEATING	COOLING
SOLAR FRACTION USED	1.862	29.100	124.775
OPERATING ENERGY	2.027	0.400	5.649
AUX. THERMAL ENERGY	N.A.	6.061	84.900
AUX. ELECTRIC FUEL	0.140	28.699	295.736
AUX. FOSSIL FUEL	N.A.	N.A.	N.A.
ELECTRICAL SAVINGS	2.234	64.376	458.032
FOSSIL SAVINGS	N.A.	N.A.	N.A.
	3.378	0.667	9.41

SYSTEM PERFORMANCE FACTOR:

0.187

* DENOTES UNAVAILABLE DATA
@ DENOTES NULL DATA
N.A. DENOTES NOT APPLICABLE DATA

REFERENCE: USER'S GUIDE TO THE MONTHLY PERFORMANCE REPORT
OF THE NATIONAL SOLAR DATA PROGRAM, FEBRUARY 28, 1978,
SOLAR/0004-78/18

SOLAR HEATING AND COOLING DEMONSTRATION PROGRAM

MONTHLY REPORT SITE SUMMARY

SITE: COLUMBIA GAS, COLUMBUS, OHIO
REPORT PERIOD: JUNE, 1978

SOLAR/9999-79/05

SITE/SYSTEM DESCRIPTION:
THE COLUMBIA GAS SOLAR ENERGY SYSTEM PROVIDES HEATING, COOLING AND DOMESTIC HOT WATER FOR A 25,000 SQ FT BUILDING. AUXILIARY HEATING AND COOLING ENERGY IS PROVIDED BY A NATURAL GAS BOILER WHICH FIRES A 100 TON ABSORPTION CHILLER OR FLOWS THROUGH FINNED-TUBE HEATING COILS AS THE LOAD DEMANDS. A SEPARATE DOMESTIC HOT WATER HEATER IS USED. THE COLLECTOR ARRAY CONSISTS OF 44 NORTH-SOUTH TRACKING CONCENTRATORS WITH A TOTAL EFFECTIVE AREA OF 2978 SQ FT. THE COLLECTOR FLUID IS A 47 PERCENT SOLUTION OF DOWTHERM SR1. THE SOLAR ENERGY IS STORED IN A 5000 GALLON THERMAL ENERGY STORAGE TANK.

GENERAL SITE DATA:

INCIDENT SOLAR ENERGY 149.192 GIGA JOULES
COLLECTED SOLAR ENERGY 539257 KJ/SQ.M.
AVERAGE AMBIENT TEMPERATURE 19.766 GIGA JOULES
AVERAGE BUILDING TEMPERATURE 71445 KJ/SQ.M.
ECSS SOLAR CONVERSION EFFICIENCY 22 DEGREES C
ECSS OPERATING ENERGY 24
TOTAL SYSTEM OPERATING ENERGY 0.05 GIGA JOULES
TOTAL ENERGY CONSUMED 97.635 GIGA JOULES
170.206 GIGA JOULES

SUBSYSTEM SUMMARY:

LOAD	FRACTION USED	HOT WATER	HEATING	COOLING	SYSTEM TOTAL
SOLAR ENERGY	1.965	30.700	131.637	164.294	GIGA JOULES
OPERATING ENERGY	2.138	0.422	5.960	7.648	GIGA JOULES
AUX. THERMAL ENG	N.A.	6.395	89.569	97.635	GIGA JOULES
AUX. ELECTRIC FUEL	0.148	30.278	312.001	343.178	GIGA JOULES
AUX. FOSSIL FUEL	N.A.	N.A.	N.A.	N.A.	GIGA JOULES
ELECTRICAL SAVINGS	2.357	67.917	483.223	553.398	GIGA JOULES
FOSSIL SAVINGS	N.A.	N.A.	N.A.	-1.670	GIGA JOULES
	3.564	0.704	9.933	12.748	GIGA JOULES

SYSTEM PERFORMANCE FACTOR:

0.187

* DENOTES UNAVAILABLE DATA
@ DENOTES NULL DATA
N.A. DENOTES NOT APPLICABLE DATA

REFERENCE: USER'S GUIDE TO THE MONTHLY PERFORMANCE REPORT
OF THE NATIONAL SOLAR DATA PROGRAM, FEBRUARY 28, 1978,
SOLAR/0004-78/18

SOLAR HEATING AND COOLING DEMONSTRATION PROGRAM

MONTHLY REPORT ENERGY COLLECTION AND STORAGE SUBSYSTEM (ECSS)

SITE: COLUMBIA GAS, COLUMBUS, OHIO
REPORT PERIOD: JUNE, 1979

SOLAR/9999-79/05

DAY OF MONTH	INCIDENT SOLAR ENERGY MILLION BTU	AMBIENT TEMP DEG-F	ENERGY TO LOADS MILLION BTU	AUX THERMAL TO ECSS MILLION BTU	ECSS OPERATING ENERGY MILLION BTU	ECSS ENERGY REJECTED MILLION BTU	ECSS SOLAR CONVERSION EFFICIENCY
1	4.278	71	0.000	NOT APPLICABLE	0.049	NOT APPLICABLE	0.000
2	5.096	69	0.001		0.072		0.000
3	4.629	71	0.000		0.058		0.000
4	4.550	73	0.005		0.061		0.037
5	5.877	75	0.004		0.035		0.001
6	3.366	73	0.000		0.017		0.004
7	2.767	75	0.011		0.014		0.021
8	2.116	76	0.000		0.035		0.000
9	3.282	74	0.000		0.051		0.000
10	3.987	65	0.109		0.076		0.000
11	5.589	66	0.123		0.087		0.039
12	4.024	65	0.101		0.038		0.025
13	5.499	73	0.121		0.056		0.023
14	6.191	78	0.142		0.083		0.000
15	5.078	76	0.000		0.044		0.000
16	4.250	69	0.096		0.046		0.021
17	4.565	72	0.141		0.101		0.080
18	7.374	76	0.181		0.061		0.031
19	5.866	70	0.152		0.029		0.081
20	2.816	77	0.132		0.084		0.045
21	5.963	69	0.000		0.054		0.000
22	5.211	69	0.000		0.054		0.000
23	8.130	65	2.297		0.109		0.253
24	6.600	69	0.069		0.083		0.147
25	5.532	73	0.080		0.002		0.014
26	5.197	77	0.132		0.060		0.025
27	1.646	69	0.096		0.004		0.058
28	1.240	62	0.000		0.002		0.000
30							
SUM	141.415	-	4.238	N.A.	1.583	N.A.	-
AVG	4.714	72	0.141	N.A.	0.053	N.A.	0.051
NBS ID	Q001	N113			Q102		N111

* DENOTES UNAVAILABLE DATA.
@ DENOTES NULL DATA.
N.A. DEVOTES NOT APPLICABLE DATA.

SOLAR HEATING AND COOLING DEMONSTRATION PROGRAM

MONTHLY REPORT COLLECTOR ARRAY PERFORMANCE

SITE: COLUMBIA GAS, COLUMBUS, OHIO
REPORT PERIOD: JUNE, 1979
SOLAR/9999-79/06

DAY OF MONTH	INCIDENT SOLAR ENERGY MILLION BTU	OPERATIONAL INCIDENT ENERGY MILLION BTU	COLLECTED SOLAR ENERGY MILLION BTU	DAYTIME AMBIENT TEMP DEG F	COLLECTOR ARRAY EFFICIENCY
1	4.278	0.000	0.000	79	0.000
2	5.096	3.051	0.783	76	0.154
3	4.629	2.386	0.614	77	0.133
4	4.650	3.085	0.944	83	0.203
5	5.877	4.159	1.388	82	0.236
6	3.366	0.000	0.000	80	0.000
7	2.767	0.000	0.000	80	0.000
8	2.116	0.000	0.000	79	0.000
9	3.287	0.710	0.082	83	0.025
10	5.577	0.827	0.102	*	0.026
11	5.892	4.782	1.468	75	0.283
12	5.024	0.552	1.677	70	0.030
13	5.499	2.614	0.871	80	0.123
14	6.191	3.276	0.763	85	0.014
15	5.078	0.653	0.073	*	0.019
16	4.250	0.472	0.082	84	0.049
17	5.565	1.103	0.222	77	0.030
18	7.374	1.832	0.275	85	0.064
19	5.866	1.691	0.375	77	0.087
20	2.816	0.867	0.244	87	0.021
21	5.963	4.046	1.258	74	0.005
22	5.211	0.354	0.025	*	0.000
23	8.130	6.468	2.557	72	0.314
24	6.600	4.969	2.033	78	0.308
25	5.532	0.000	0.000	82	0.000
26	5.197	0.845	0.152	82	0.029
27	1.646	0.000	0.000	70	0.000
28	1.240	0.000	0.000	64	0.000
29					
30					
SUM	141.415	58.729	18.736	-	-
AVG	4.714	1.958	0.625	78	0.132
NBSID	Q001		Q100		N100

* DENOTES UNAVAILABLE DATA.
@ DENOTES NULL DATA.
N.A. DENOTES NOT APPLICABLE DATA.

SOLAR HEATING AND COOLING DEMONSTRATION PROGRAM

MONTHLY REPORT STORAGE PERFORMANCE

SITE: COLUMBIA GAS, COLUMBUS, OHIO
REPORT PERIOD: JUNE, 1979
SOLAR/9999-79/06

DAY OF MONTH	ENERGY TO STORAGE MILLION BTU	ENERGY FROM STORAGE MILLION BTU	CHANGE IN STORAGE MILLION BTU	STORAGE AVERAGE TEMP DEG F	STORAGE EFFICIENCY
1	0.000	0.000	-0.398	151	1.000
2	0.610	0.001	0.664	156	1.090
3	0.573	0.000	0.323	166	0.564
4	0.862	0.058	0.129	174	0.216
5	1.327	0.005	0.176	171	-0.280
6	0.000	0.004	-0.362	161	1.000
7	0.000	0.011	-0.382	151	1.000
8	0.000	0.045	-0.376	148	1.000
9	0.045	0.000	0.045	138	0.426
10	0.066	0.000	0.066	136	-1.454
11	1.187	0.109	0.992	151	0.927
12	1.439	0.123	0.861	175	0.684
13	0.074	0.101	-0.466	175	-0.953
14	0.707	0.121	0.439	182	-0.792
15	0.575	0.142	0.080	177	0.390
16	0.021	0.001	0.450	167	-21.506
17	0.062	0.096	-0.274	172	-4.430
18	0.158	0.000	0.236	175	-0.888
19	2.084	0.141	1.084	182	-0.354
20	0.292	0.152	-0.213	173	-0.351
21	1.082	0.132	0.478	174	-1.564
22	0.016	0.000	-0.326	176	-20.810
23	0.985	1.229	-0.563	176	0.432
24	1.838	0.069	0.801	174	0.419
25	0.000	0.080	-0.132	183	1.000
26	0.111	0.132	-0.341	177	-1.880
27	0.000	0.096	-0.528	161	1.000
28	0.000	0.000	-0.409	153	1.000
29	0.000	0.000	-0.409	153	1.000
30	0.000	0.000	-0.409	153	1.000
SUM	14.817	2.133	-0.303	-	-
AVG	0.494	0.104	-0.010	166	0.191
NBS ID	Q200	Q201	Q202		N108

* DENOTES UNAVAILABLE DATA.
@ DENOTES NULL DATA.
N.A. DENOTES NOT APPLICABLE DATA.

SOLAR HEATING AND COOLING DEMONSTRATION PROGRAM

MONTHLY REPORT HOT WATER SUBSYSTEM

SITE: COLUMBIA GAS, COLUMBUS, OHIO
REPORT PERIOD: JUNE, 1979
SOLAR/99999-79/06

DAY OF MON.	HOT WATER LOAD MILLION BTU	SOLAR FR. OF LOAD PER CENT	SOLAR ENERGY USED MILLION BTU	OPER ENERGY MILLION BTU	AUX THERMAL USED MILLION BTU	AUX ELECT FUEL MILLION BTU	AUX FOSSIL FUEL MILLION BTU	ELECT ENERGY SAVINGS MILLION BTU	FOSSIL ENERGY SAVINGS MILLION BTU	SUP. WAT. TEMP DEG F	HOT WAT. TEMP DEG F	HOT WATER USED GAL
1	0.001	0	0.000	NOT APPLICABLE	0.000	NOT APPLICABLE	0.000	NOT APPLICABLE	0.000	66	112	156
2	0.001	10	0.001	NOT APPLICABLE	0.000	NOT APPLICABLE	0.000	NOT APPLICABLE	0.000	71	103	205
3	0.000	78	0.000	NOT APPLICABLE	0.000	NOT APPLICABLE	0.000	NOT APPLICABLE	0.000	71	103	262
4	0.080	84	0.058	NOT APPLICABLE	0.002	NOT APPLICABLE	0.002	NOT APPLICABLE	0.002	67	101	302
5	0.079	87	0.055	NOT APPLICABLE	0.001	NOT APPLICABLE	0.001	NOT APPLICABLE	0.001	67	101	302
6	0.076	80	0.041	NOT APPLICABLE	0.004	NOT APPLICABLE	0.004	NOT APPLICABLE	0.004	68	101	254
7	0.080	82	0.045	NOT APPLICABLE	0.006	NOT APPLICABLE	0.006	NOT APPLICABLE	0.006	71	107	178
8	0.088	95	0.000	NOT APPLICABLE	0.000	NOT APPLICABLE	0.000	NOT APPLICABLE	0.000	70	98	178
9	0.000	91	0.000	NOT APPLICABLE	0.000	NOT APPLICABLE	0.000	NOT APPLICABLE	0.000	70	98	158
10	0.036	99	0.109	NOT APPLICABLE	0.011	NOT APPLICABLE	0.011	NOT APPLICABLE	0.011	70	131	158
11	0.080	99	0.121	NOT APPLICABLE	0.001	NOT APPLICABLE	0.001	NOT APPLICABLE	0.001	70	131	158
12	0.096	99	0.142	NOT APPLICABLE	0.001	NOT APPLICABLE	0.001	NOT APPLICABLE	0.001	71	133	158
13	0.096	100	0.142	NOT APPLICABLE	0.000	NOT APPLICABLE	0.000	NOT APPLICABLE	0.000	71	133	158
14	0.091	99	0.100	NOT APPLICABLE	0.000	NOT APPLICABLE	0.000	NOT APPLICABLE	0.000	71	133	158
15	0.080	99	0.096	NOT APPLICABLE	0.000	NOT APPLICABLE	0.000	NOT APPLICABLE	0.000	71	133	158
16	0.080	99	0.141	NOT APPLICABLE	0.004	NOT APPLICABLE	0.004	NOT APPLICABLE	0.004	71	133	158
17	0.126	100	0.181	NOT APPLICABLE	0.003	NOT APPLICABLE	0.003	NOT APPLICABLE	0.003	71	133	158
18	0.120	98	0.152	NOT APPLICABLE	0.000	NOT APPLICABLE	0.000	NOT APPLICABLE	0.000	71	133	158
19	0.106	99	0.132	NOT APPLICABLE	0.001	NOT APPLICABLE	0.001	NOT APPLICABLE	0.001	71	133	158
20	0.000	100	0.000	NOT APPLICABLE	0.000	NOT APPLICABLE	0.000	NOT APPLICABLE	0.000	71	133	158
21	0.000	100	0.000	NOT APPLICABLE	0.000	NOT APPLICABLE	0.000	NOT APPLICABLE	0.000	71	133	158
22	0.000	100	0.000	NOT APPLICABLE	0.000	NOT APPLICABLE	0.000	NOT APPLICABLE	0.000	71	133	158
23	0.000	100	0.000	NOT APPLICABLE	0.000	NOT APPLICABLE	0.000	NOT APPLICABLE	0.000	71	133	158
24	0.000	100	0.000	NOT APPLICABLE	0.000	NOT APPLICABLE	0.000	NOT APPLICABLE	0.000	71	133	158
25	0.000	100	0.000	NOT APPLICABLE	0.000	NOT APPLICABLE	0.000	NOT APPLICABLE	0.000	71	133	158
26	0.000	100	0.000	NOT APPLICABLE	0.000	NOT APPLICABLE	0.000	NOT APPLICABLE	0.000	71	133	158
27	0.000	100	0.000	NOT APPLICABLE	0.000	NOT APPLICABLE	0.000	NOT APPLICABLE	0.000	71	133	158
28	0.000	100	0.000	NOT APPLICABLE	0.000	NOT APPLICABLE	0.000	NOT APPLICABLE	0.000	71	133	158
29	0.000	100	0.000	NOT APPLICABLE	0.000	NOT APPLICABLE	0.000	NOT APPLICABLE	0.000	71	133	158
30	0.000	100	0.000	NOT APPLICABLE	0.000	NOT APPLICABLE	0.000	NOT APPLICABLE	0.000	71	133	158
SUM	1.862	-	2.027	N.A.	0.140	N.A.	2.234	N.A.	3.378	-	-	4221
AVG	0.062	93	0.068	N.A.	0.005	N.A.	0.074	N.A.	0.113	71	120	141
NBS	Q302	N300	Q300	Q303	Q301	Q305	Q306	Q311	Q313	N305	N307	N308

* DENOTES UNAVAILABLE DATA.
@ DENOTES NULL DATA.
N.A. DENOTES NOT APPLICABLE DATA.

SOLAR HEATING AND COOLING DEMONSTRATION PROGRAM

MONTHLY REPORT SPACE HEATING SUBSYSTEM

SITE: COLUMBIA GAS, CO., JMBUS, OHIO
REPORT PERIOD: JUNE, 1979
SOLAR/9999-79/06

DAY OF MOV.	SPACE HEATING LOAD MILLION BTU	SOLAR FR. OF LOAD PCT	SOLAR ENERGY USED MILLION BTU	OPER ENERGY MILLION BTU	AUX THERMAL USED MILLION BTU	AUX ELECT FUEL MILLION BTU	AUX FOSSIL FUEL MILLION BTU	ELECT ENERGY SAVINGS MILLION RTU	FOSSIL ENERGY SAVINGS MILLION BTU	BLDG TEMP DEG. F	AMB TEMP DEG. F
1	0.990	0	0.000	0.236	0.990	NOT APPLICABLE			0.000	76	71
2	1.149	0	0.000	0.326	1.149	NOT APPLICABLE			0.000	75	69
3	0.964	0	0.000	0.260	0.964	NOT APPLICABLE			0.000	75	71
4	0.917	0	0.000	0.199	0.917	NOT APPLICABLE			0.000	75	73
5	0.592	0	0.000	0.145	0.592	NOT APPLICABLE			0.000	76	75
6	0.611	0	0.000	0.177	0.611	NOT APPLICABLE			0.000	76	73
7	0.544	0	0.000	0.149	0.544	NOT APPLICABLE			0.000	76	75
8	0.555	0	0.000	0.140	0.555	NOT APPLICABLE			0.000	75	75
9	0.300	0	0.000	0.000	0.300	NOT APPLICABLE			0.000	75	76
10	0.432	0	0.000	0.111	0.432	NOT APPLICABLE			0.000	75	74
11	2.181	0	0.000	0.379	2.181	NOT APPLICABLE			0.000	75	65
12	2.067	0	0.000	0.338	2.067	NOT APPLICABLE			0.000	75	65
13	1.807	0	0.000	0.227	1.807	NOT APPLICABLE			0.000	76	63
14	1.152	0	0.000	0.088	1.152	NOT APPLICABLE			0.000	76	78
15	0.436	0	0.000	0.110	0.436	NOT APPLICABLE			0.000	76	76
16	0.410	0	0.000	0.114	0.410	NOT APPLICABLE			0.000	76	76
17	1.324	0	0.000	0.247	1.324	NOT APPLICABLE			0.000	76	69
18	0.916	0	0.000	0.164	0.916	NOT APPLICABLE			0.000	77	72
19	0.530	0	0.000	0.134	0.530	NOT APPLICABLE			0.000	77	76
20	1.110	0	0.000	0.211	1.110	NOT APPLICABLE			0.000	77	70
21	0.530	0	0.000	0.101	0.530	NOT APPLICABLE			0.000	76	77
22	0.967	0	0.000	0.189	0.967	NOT APPLICABLE			0.000	76	69
23	*	*	*	*	*	NOT APPLICABLE			0.000	76	69
24	2.946	13	0.387	0.548	2.559	NOT APPLICABLE			0.645	76	65
25	1.547	0	0.000	0.237	1.547	NOT APPLICABLE			0.000	76	69
26	1.051	0	0.000	0.187	1.051	NOT APPLICABLE			0.000	76	73
27	0.000	0	0.000	0.000	0.000	NOT APPLICABLE			0.000	77	77
28	0.000	0	0.000	0.000	0.000	NOT APPLICABLE			0.000	77	69
29	0.200	0	0.000	0.049	0.200	NOT APPLICABLE			0.000	75	62
30	1.512	0	0.000	0.416	1.512	NOT APPLICABLE			0.000	-	-
SUM	29.100	-	0.400	6.061	28.699	N.A.	64.376	N.A.	0.667	-	-
AVG	0.970	1	0.013	0.202	0.957	N.A.	2.146	N.A.	0.022	76	72
NBS	Q402	N400	Q400	Q403	Q401		Q410	Q415	Q417	N406	N113

* DENOTES UNAVAILABLE DATA.
@ DENOTES NULL DATA.
N.A. DENOTES NOT APPLICABLE DATA.

SOLAR HEATING AND COOLING DEMONSTRATION PROGRAM

MONTHLY REPORT SPACE COOLING SUBSYSTEM

SITE: COLUMBIA GAS, COLUMBUS, OHIO
REPORT PERIOD: JUNE, 1979

SOLAR/9993-79/06

DAY OF MON.	SPACE COOLING LOAD MILLION BTU	SOLAR FR.OF LOAD PCT	SOLAR ENERGY USED MILLION BTU	OPER ENERGY MILLION BTU	AUX THERMAL USED MILLION BTU	AUX ELECT FUEL MILLION BTU	AUX FOSSIL FUEL MILLION BTU	ELECT ENERGY SAVINGS MILLION BTU	FOSSIL ENERGY SAVINGS MILLION BTU	BLDG DRY BULB TEMP F	AMB TEMP DEG F
1	5.399	0	0.000	3.034	10.574	NOT	15.836	NOT	0.000	76	71
2	5.545	0	0.000	2.173	6.785	NOT	9.228	NOT	0.000	75	69
3	2.371	0	0.000	2.194	6.842	NOT	9.501	NOT	0.000	75	71
4	2.642	1	0.098	2.846	9.687	NOT	14.764	NOT	0.163	75	73
5	4.815	15	1.386	2.930	9.164	NOT	14.134	NOT	2.310	76	75
6	5.171	0	0.000	3.181	10.621	NOT	16.599	NOT	0.000	76	73
7	5.241	0	0.000	3.172	10.689	NOT	16.601	NOT	0.000	76	73
8	5.042	0	0.000	3.236	10.700	NOT	16.596	NOT	0.000	76	75
9	2.932	0	0.000	3.339	10.245	NOT	12.890	NOT	0.000	75	76
10	1.932	0	0.000	2.827	6.359	NOT	16.104	NOT	0.000	75	74
11	4.657	0	0.105	2.717	10.526	NOT	13.736	NOT	0.174	75	65
12	4.315	1	0.000	2.638	9.427	NOT	14.524	NOT	0.000	75	65
13	4.429	0	0.000	2.870	9.957	NOT	14.896	NOT	0.000	76	65
14	4.416	0	0.000	2.375	9.809	NOT	14.343	NOT	0.000	76	73
15	5.085	0	0.000	2.474	11.118	NOT	12.128	NOT	0.000	76	76
16	2.654	0	0.000	2.585	7.230	NOT	11.837	NOT	0.000	76	76
17	2.461	0	0.000	2.475	12.406	NOT	19.172	NOT	0.744	76	69
18	2.224	0	0.000	2.920	12.978	NOT	18.464	NOT	0.000	76	72
19	2.325	4	0.447	3.020	11.408	NOT	24.334	NOT	0.000	77	76
20	5.375	0	0.000	3.221	11.280	NOT	21.640	NOT	0.128	77	70
21	5.570	0	0.077	3.254	13.910	NOT	22.316	NOT	0.232	77	70
22	5.190	1	0.139	3.247	14.294	NOT	13.283	NOT	0.000	76	69
23	2.726	0	0.000	2.344	7.774	NOT	14.283	NOT	0.000	76	69
24	3.609	27	2.350	2.412	8.660	NOT	14.236	NOT	3.916	76	65
25	3.907	9	0.860	2.805	10.626	NOT	15.749	NOT	1.434	76	69
26	7.753	0	0.000	2.820	10.254	NOT	16.225	NOT	0.000	76	73
27	4.800	0	0.000	3.129	10.337	NOT	16.097	NOT	0.000	77	77
28	4.259	0	0.000	3.056	9.260	NOT	14.955	NOT	0.000	77	69
29	2.426	0	0.000	2.089	6.928	NOT	18.339	NOT	0.000	75	62
30											
SUM	124.775	-	5.649	84.900	295.736	N.A.	458.032	N.A.	9.415	-	-
AVG	4.159	2	0.188	2.830	9.857	N.A.	15.268	N.A.	0.314	76	72
NBS	Q502	N500	Q500	Q503	Q501		Q508	Q512	Q514	N406	N113

* DENOTES UNAVAILABLE DATA.
@ DENOTES NULL DATA.
N.A. DENOTES NOT APPLICABLE DATA.

SOLAR HEATING AND COOLING DEMONSTRATION PROGRAM
MONTHLY REPORT
ENVIRONMENTAL SUMMARY

SITE: COLUMBIA GAS, COLUMBUS, OHIO
REPORT PERIOD: JUNE, 1979
SOLAR/99999-79/06

DAY OF MONTH	TOTAL INSOLATION BTU/SQ.FT	DIFFUSE INSOLATION BTU/SQ.FT	AMBIENT TEMPERATURE DEG F	DAYTIME AMBIENT TEMP DEG F	RELATIVE HUMIDITY PERCENT	WIND DIRECTION DEGREES	WIND SPEED M.P.H.
1	1437	908	71	79	NOT APPLICABLE	NOT APPLICABLE	NOT APPLICABLE
2	1711	758	69	76			
3	1555	709	71	77			
4	1552	558	73	82			
5	1974	628	75	80			
6	1130	765	73	80			
7	1929	759	75	79			
8	711	600	76	83			
9	1102	734	74	8*			
10	1339	795	75	75			
11	1873	556	65	70			
12	1378	398	65	70			
13	1351	897	78	85			
14	1846	595	73	8*			
15	2079	774	76	84			
16	1707	937	69	75			
17	1423	851	72	87			
18	1533	919	76	74			
19	2476	507	69	75			
20	1970	944	70	87			
21	1946	520	77	84			
22	2002	620	69	74			
23	1750	981	6*	74			
24	2730	375	65	72			
25	2216	364	69	78			
26	1358	920	73	82			
27	1745	928	77	82			
28	1553	490	69	70			
29	416	396	62	64			
SUM	47486	20892	-	-	-	-	-
AVG	1583	696	72	78	N.A.	N.A.	N.A.
NBS ID	Q001		N113			N115	N114

* DENOTES UNAVAILABLE DATA.

@ DENOTES NULL DATA.

N.A. DENOTES NOT APPLICABLE DATA.

SCLAR HEATING AND COOLING DEMONSTRATION PROGRAM

MONTHLY REPORT THERMODYNAMIC CONVERSION EQUIPMENT

SITE: COLUMBIA GAS, COLUMBUS, OHIO
REPORT PERIOD: JUNE, 1979
SOLAR/9999-79/06

DAY OF MONTH	EQUIPMENT LOAD MILLION BTU	THERMAL ENERGY INPUT MILLION BTU	OPERATING ENERGY MILLION BTU	ENERGY REJECTED MILLION BTU	COEFFICIENT OF PERFORMANCE (SEE NOTE)
1	5.399	10.574	2.087	17.482	0.511
2	2.545	6.785	1.718	10.612	0.375
3	2.371	6.842	1.701	10.264	0.347
4	4.642	9.785	1.876	15.867	0.474
5	4.815	10.550	1.900	16.936	0.456
6	5.171	10.621	2.173	17.913	0.487
7	5.241	10.689	2.175	17.690	0.490
8	5.042	10.700	2.248	17.701	0.471
9	2.472	6.245	2.352	10.404	0.341
10	1.932	6.359	2.227	18.493	0.308
11	4.657	10.593	2.795	17.475	0.440
12	4.315	9.530	1.747	15.862	0.453
13	4.429	9.957	1.754	15.862	0.450
14	4.416	9.809	1.939	15.714	0.447
15	5.085	11.373	2.229	18.386	0.473
16	2.654	7.118	1.879	10.585	0.373
17	2.461	7.220	1.996	19.425	0.421
18	5.132	12.424	1.944	19.425	0.421
19	5.137	15.280	2.154	22.368	0.352
20	5.570	13.987	2.223	22.964	0.398
21	5.190	14.433	2.186	22.047	0.360
22	2.726	7.774	1.772	11.699	0.351
23	#	#	#	#	*
24	3.609	11.010	1.545	16.057	0.328
25	3.907	11.487	1.824	16.208	0.340
26	4.753	10.254	1.831	17.141	0.463
27	4.800	10.337	1.990	16.638	0.464
28	4.259	9.260	2.011	14.994	0.460
29	2.426	6.928	1.707	9.829	0.350
30					
SUM	124.775	301.385	58.779	471.507	0.414
AVG	4.159	10.046	1.959	15.717	0.014

* DENOTES UNAVAILABLE DATA.
@ DENOTES NULL DATA.
N.A. DENOTES NOT APPLICABLE DATA.
NOTE:

SOLAR HEATING AND COOLING DEMONSTRATION PROGRAM
MONTHLY REPORT
EXTRA LOAD SUBSYSTEM

SITE: COLUMBIA GAS, COLUMBUS, OHIO
REPORT PERIOD: JUNE, 1979
SOLAR/9999-79/06

DAY OF MONTH	LOAD MILLION BTU	SOLAR FRACTION OF LOAD PERCENT	SOLAR ENERGY USED MILLION BTU	OPER ENERGY MILLION BTU	AUX THERMAL MILLION BTU	AUX ELECT FUEL MILLION BTU	AUX FOSSIL FUEL MILLION BTU	ELECT ENERGY SAVINGS MILLION BTU	FOSSIL ENERGY SAVINGS MILLION BTU
1	6.484	0	0.000	3.270	6.484		18.504		0.000
2	7.228	0	0.000	2.499	7.228		13.490		0.000
3	5.947	0	0.000	2.454	5.947		12.732		0.000
4	5.360	0	0.000	3.045	5.360		17.082		0.000
5	4.355	0	0.000	3.078	4.355		15.724		0.000
6	5.183	0	0.000	3.349	5.183		18.121		0.000
7	4.000	0	0.000	3.385	4.000		18.130		0.000
8	2.163	0	0.000	3.013	2.163		12.596		0.000
9	12.489	0	0.000	2.840	0.000		11.788		0.000
10	10.035	0	0.000	3.088	12.489		20.017		0.000
11	10.086	0	0.000	3.015	10.086		18.036		0.000
12	6.795	0	0.000	3.096	10.086		17.517		0.000
13	3.399	0	0.000	3.293	3.399		19.051		0.000
14	3.592	0	0.000	3.592	3.592		13.121		0.000
15	3.210	0	0.000	2.589	3.210		21.043		0.000
16	11.760	0	0.000	3.167	11.760		21.043		0.000
17	6.254	0	0.000	3.184	6.254		20.056		0.000
18	6.452	0	0.000	3.355	6.452		25.122		0.000
19	14.520	0	0.000	3.469	14.520		23.382		0.000
20	7.243	0	0.000	3.533	7.243		14.194		0.000
21	15.936	*	2.983	2.959	*		19.003		4.972
22	7.526	0	0.000	3.043	12.953		18.406		0.000
23	5.572	0	0.000	3.007	7.526		18.194		0.000
24	0.000	0	0.000	3.129	5.572		16.097		0.000
25	1.217	0	0.000	3.105	0.000		15.605		0.000
26	9.875	0	0.000	2.505	1.217		13.726		0.000
27	190.004		3.086	90.961	186.918	N.A.	522.409	N.A.	5.143
28	6.333	0	0.103	3.032	6.231	N.A.	17.414	N.A.	0.171
29									
30									
SUM									
AVG									

* DENOTES UNAVAILABLE DATA.
@ DENOTES NULL DATA.
N.A. DENOTES NOT APPLICABLE DATA.

UNIVERSITY OF FLORIDA



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